USGS
science for a changing world

EROS Data Center
Earth Images for Education

Tracking Change Over Time

U.S. Geological Survey
EROS Data Center
30
1973–2003
THREE DECADES OF DISCOVERY

U.S. Department of the Interior
U.S. Geological Survey

Tracking Change Over Time: A Classroom Activity

The Earth's surface is constantly changing. Continents shift. Seacoasts erode. Cities grow. Floodwaters cover one region while drought scorches another.

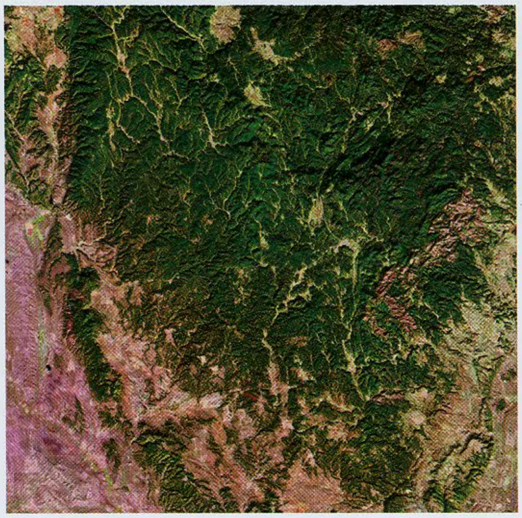
It's hard to see these changes from ground level. A much broader view is needed, together with a consistent record of change over time. Satellites that capture images of large areas of the Earth's surface at regular intervals can provide this view. By comparing satellite images from different times, it's possible not only to see changes, but to understand their effects.

The images on these two pages were taken by Landsat satellites. The images span 30 years and are archived at the EROS Data Center. Satellite images are somewhat different than pictures taken with a camera. Satellite sensors record waves of light and heat energy coming off the Earth's surface. Different sets of these energy waves are called bands. Images are created by putting together several bands (usually three). Various combinations of bands make it possible to see certain types of things in a satellite image that you couldn't see in an ordinary photograph.

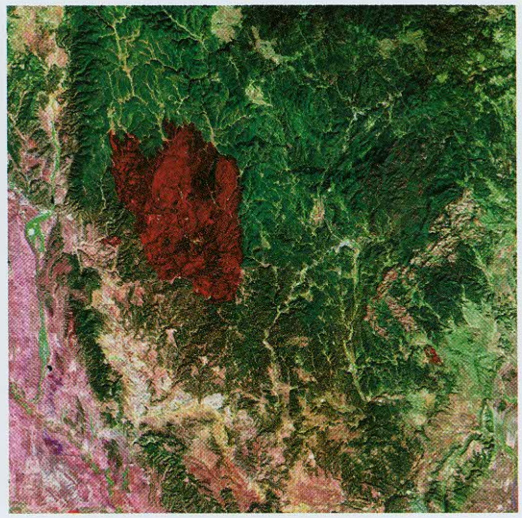
Scientists compare images like these in order to learn more about changes taking place in a region, across the country, and around the world. Compare the images in each set. What changes do you see? A detailed classroom activity can be built around these image sets using either the EDC Earth Images for Education: Tracking Change Over Time Lesson Plan and CD or by downloading the images directly from the Internet. To download the images, go to http://earthscience4kids.cr.usgs.gov; to manipulate the bands on the images, use MultiSpec (freeware), which is available at http://dynamo.ecn.purdue.edu/~biehl/MultiSpec/.

Black Hills, South Dakota

Fire can change a landscape tremendously in a very short time. In these satellite images of the Black Hills of South Dakota, healthy evergreen forests appear in shades of green. Forest fires leave "scars" on the landscape where trees and other vegetation have been burned away. Fire scars are clearly visible in shades of red in this series of satellite images, which spans four consecutive years.



1999



2000

2001

2002

Lesson Plan

Purpose of the lesson

How does satellite imagery illustrate global change on Earth? Landsat 7 is a tool used to achieve improved understanding of the Earth's land surfaces and the impact of humans on the environment. Use the Earth Images for Education: Tracking Change Over Time *folder with the accompanying CD, or the Classroom Activity Guide on page 4 of this insert, to help students investigate how satellite images are used to study land surface change over time.*

Background

The USGS EROS Data Center (EDC) houses a remarkable archive. Archives are like libraries. But instead of books, the archive at EDC contains satellite images. These images provide scientists with a unique historical record of global change. One of the primary satellites used by scientists at the Data Center is Landsat 7. Landsat 7 images the Earth from 705 kilometers (km) above the planet's surface. The satellite makes a complete trip around the Earth every 99 minutes and takes a complete set of images of the land surfaces every 16 days. A single satellite image, or scene, covers an area that is 183 km wide by 170 km long. One pixel on the image represents 30 meters on the Earth. Using multiple spectral bands, images are created that scientists use to monitor rainforest deforestation, droughts, coastline change, floods, the impact of wars, and many other changes to the land surface.

Image Set 1 – Black Hills, South Dakota[1] This series of images demonstrates the amount of change that can be seen over a relatively brief period. Fire can change the landscape tremendously and an example is the Black Hills of South Dakota. In the images, compare how the landscape changed after each fire season. The fire scars are clearly visible in shades of red. Using short-wave infrared (bands 5,4,2), fire scars are easily discernable from the green coniferous forests surrounding them. Some estimates put the total acreage burned in this four-year period at around 10% of the Black Hills.

Image Set 2 – Las Vegas, Nevada[2] Las Vegas provides a dramatic illustration of the spatial patterns and rates of change that result in urban sprawl. Population growth in the Las Vegas Valley was fairly slow during the first half of this century, but as the gaming and tourism industry blossomed, population began to increase rapidly. For example, the population of Las Vegas in 1950 was 24,624; in 1960 it increased to 64,405. By 1980 the city had a population of 164,674 and today, Las Vegas Valley's population tops one million – and this doesn't include the tourists! The 1972 satellite image shows the status of Las Vegas as just a stop along the railroad that passed through the town. By 2000, the town had grown and sprawled in almost all directions, but primarily to the northwest and southeast.

Image Set 3 – Mississippi Delta, Louisiana[3] This comparison shows three decades of change in the birdsfoot delta of the Mississippi River. The delta marks the termination of the Mississippi River as it deposits sediments into the Gulf of Mexico in Louisiana. The Mississippi-Missouri River system collects eroded debris from the entire central half of the United States. Upon reaching the gulf, the river's velocity slows abruptly, reducing its capacity to carry suspended mud and sand. This sediment is deposited in an alluvial fan pattern. The delta has changed form many times over the past 10,000 years, and has varied in location along a 200-mile stretch of coastline. The birdsfoot delta has only occupied its current location for approximately 600 years. Indications that the Mississippi River was about to abandon its current course and divert through the Atchafalaya River led the U.S. Army Corps of Engineers to construct a series of dams, locks, and canals to ensure that the river channel did not change its course and negatively impact New Orleans and the region's shipping industry. In order to maintain a navigable river system, it is vital that the river does not change its current path. The images shown here from 1973, 1989, and 2003 show a delta that has experienced significant changes in just the past three decades. The most notable change is the loss of marsh along the southern edge of the delta on the left side of each image. The seafood industry is very concerned about this loss. Fish and wildlife populations are threatened as their natural habitat slowly disappears. The appearance of dams and artificial channeling along the Mississippi-Missouri River system has decreased the amount of sediment that the currents carry. The Mississippi Delta undergoes subsidence, or the gradual sinking of the delta into the gulf, over time. Before the dams and channeling were incorporated into the Mississippi-Missouri River system, sediments would cause the delta to grow at a faster rate than the subsidence could cause it to disappear. However, with a lighter sediment load moving down the channel, the opposite condition exists, where the delta subsides faster than it can be built up.

Pollution and the cutting of new waterways for petroleum exploration and drilling have also taken their toll on the delta. An increase in mean sea level during the past century has increased erosion of delta material and marshes. Due to subsidence, erosion, and sea-level rise, saltwater intrusion has occurred in freshwater habitats. As freshwater vegetation died, erosion continued and allowed more saltwater intrusion. This condition has been exacerbated by less fresh water arriving in the delta due to river control and bayou restoration projects directing water to other drainage channels. Other marsh reductions have occurred from controlled burns to promote muskrat habitat and nutria grazing.

Another change that has occurred within the past three decades is due to the lengthening of the navigation channels, which makes it appear that the overall delta is growing when it is actually shrinking. This effect is most notable in the "toes" of the birdsfoot at the southeastern edge of the delta. As you can see, the channels are much better defined in the 2003 image than in the other images. The main visible change to the birdsfoot portion of the delta in the 2003 image is the emergence of new marsh vegetation. This is directly caused by the addition of artificial "crevasses" (cuts in the natural river levee). These have resulted in emergent marsh formation within a couple of years of creating the crevasses. This technique would work higher in the delta as well, but breaching the levee in upstream locations is not feasible.

Image Set 4 – Al Isawiyah, Saudi Arabia[4] Saudi Arabia, although rich with oil, is lacking a more vital natural resource: water. The kingdom decided to diversify its economy and modernize its agricultural sector in order to become more self-supporting to meet the country's growing demand for wheat. Since Saudi Arabia has severely limited water resources, the government decided to use the revenues from the oil industry to adopt the best technologies available for farming in arid and semi-arid environments. Center pivot irrigation was introduced in Wadi as Sirhan, an area that lies 300 meters below the surrounding plateau. Located in the extreme north along the border with Jordan, Wadi as Sirhan is a remnant of an ancient inland sea and is underlain by four aquifers, two of which contain ancient water more than 20,000 years old. These three satellite images from 1986 to 2000 show the transformation of desert to agriculture through center pivot irrigation. The 1986 image shows Wadi as Sirhan near the village of Al Isawiyah before the introduction of center pivot irrigation. The 1991 image shows the region shortly after the introduction of center pivot irrigation (green circles are irrigated fields). The 2000 image shows the spread of center pivot irrigation throughout the region.

[1]UNEP (2003), "Selected Satellite Images of Our Changing Environment." UNEP/DEWA/RS.03-1. Division of Early Warning and Assessment (DEWA). United Nations Environment Programme (UNEP), P.O. Box 30552, Nairobi, Kenya
[2]same
[3]USGS. 2003. Landsat Project Change Over Time. USGS. http://landsat7.usgs.gov/gallery/change/218/
[4]USGS. 2003. Landsat Project Change Over Time. USGS. http://landsat7.usgs.gov/gallery/change/210/

Landsat 7: Explanation of Bands

Band 1 0.45-0.52 micrometers	Band 2 0.52-0.60 micrometers	Band 3 0.63-0.69 micrometers	Band 4 0.76-0.90 micrometers	Band 5 1.55-1.75 micrometers	Band 6 10.5-12.5 micrometers	Band 7 2.08-2.35 micrometers
(blue-green)	(green)	(red)	(near-infrared)	(mid-infrared)	(thermal infrared)	(mid-infrared)
Recommended for water body penetration, soil and vegetation discrimination, and forest-type mapping (deciduous/coniferous).	Recommended for vegetation discrimination and plant vigor. This band corresponds to the green reflectance of healthy vegetation.	Recommended for detecting cultural features, bare soils, and vegetation types. This band operates in the chlorophyll absorption region. The red chlorophyll absorption band of healthy green vegetation is one of the most important bands for vegetation discrimination. It is also useful for soil boundary and geological boundary mapping.	Recommended for separating water bodies from vegetation and discriminating soil moisture. It is not as effective as Band 3 for road identification. It is useful for crop identification, and emphasizes soil, crop, and land-water contrasts.	Recommended for determining roads, bare soils, and water. It also provides a good contrast between different types of vegetation and has excellent atmospheric and haze penetration. This reflective-IR band is sensitive to turgidity -- the amount of water in plants. Turgidity is useful in drought and plant vigor studies. In addition, this band can be used to discriminate among clouds, snow, and ice (important in hydrologic research) as well as to remove the effects of thin clouds and smoke. Band 5 is considered to be the best single band.	Recommended for measuring plant heat stress and thermal mapping. This band responds to thermal (heat) radiation. Thermal radiation is closely related to soil moisture and the height and temperature of vegetation. This band measures the amount of infrared radiant flux (heat) emitted from surfaces. Band 6 is used in locating geothermal activity, thermal inertia mapping, vegetation classification, vegetation stress analysis, and in measuring soil moisture.	Recommended for detecting mineral and rock types, interpreting vegetation coverage, and soil moisture. This band is used to discriminate among various rock formations. It is particularly effective in identifying zones of hydrothermal alteration in rocks.

Example of How Different Band Combinations Reveal Different Kinds of Information

Martis Forest Fire, Reno, NV

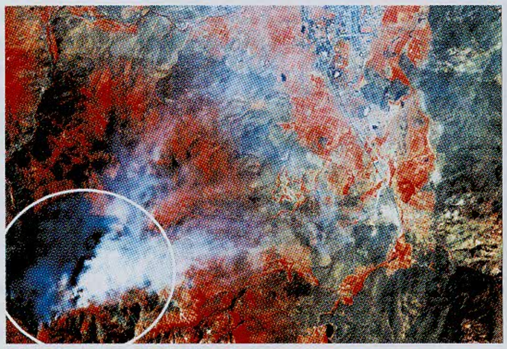
Landsat 7 images acquired June 19, 2001

Pixel size = 30 meter, including the thermal band, which is usually 60-meter resolution

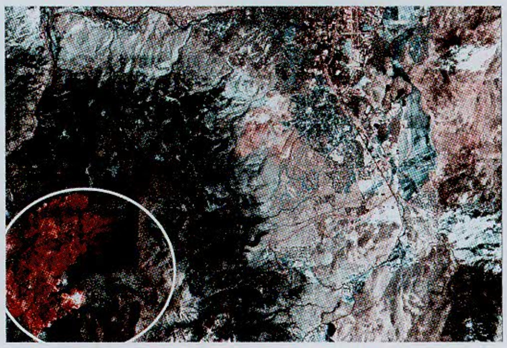
Since different kinds of surface features reflect energy picked up by satellite sensors in different amounts in each band, the appearance of surface features may vary with different band combinations. Refer to the chart above for band descriptions as you examine the images to the right and read the descriptions at the top of the following page.

Bands 3, 2, 1

Bands 5, 4, 2



Bands 4, 3, 2



Bands 6, 5, 5

Example Bands 3,2,1 – Bands 3,2,1 show what our eyes would see, that is, natural color. With this combination it is difficult to locate the fire or extent of the burn. Smoke obscures the fire area. The city of Reno is in the top right corner. Features to investigate: the fire area, hot spots along the edge of the fire, and areas of urban growth. Look for roads; they appear white/blue.

Example Bands 5,4,2 – Bands 5,4,2 reveal the fire (red) in the center of the circle but smoke still covers the area. Other red areas indicate land; green indicates vegetation and purple shows the extent of the fire. The city is peeking through the top right corner; roads are light purple.

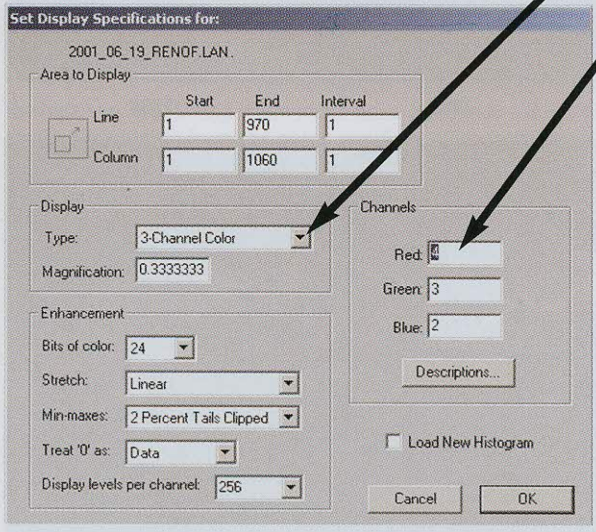
Example Bands 4,3,2 – Bands 4,3,2 indicate vegetation; forested areas appear red. The actual fire area is still clouded in smoke. The streets of the city are barely visible in the upper right quadrant (look for white areas with straight shapes).

Example Bands 6,5,5 – Bands 6,5,5 shows the fire burn area as bright red. By using band 5 in both the green and blue wavelengths, it is possible to filter through the smoke layer entirely.

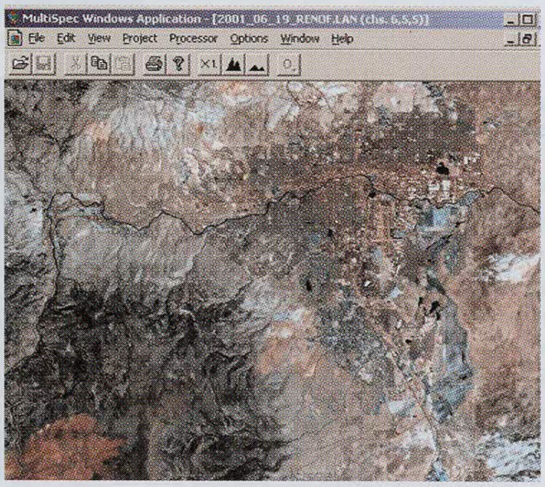
For the Computer User: Using MultiSpec and Image CD

To run MultiSpec:

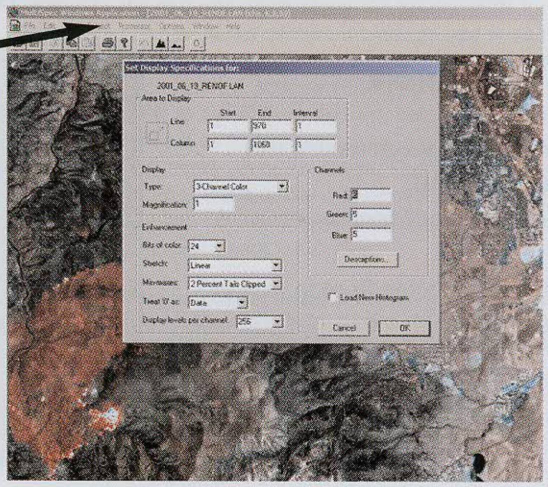
1. Go to File.
2. Click on Open.
3. Open Folder and select an image.
4. This screen will appear:



5. Under Display, Type, select 3-Channel Color.
6. Under Channels, enter desired band numbers for RED, GREEN, and BLUE. (see chart on previous page)
7. Click OK; the image will appear:



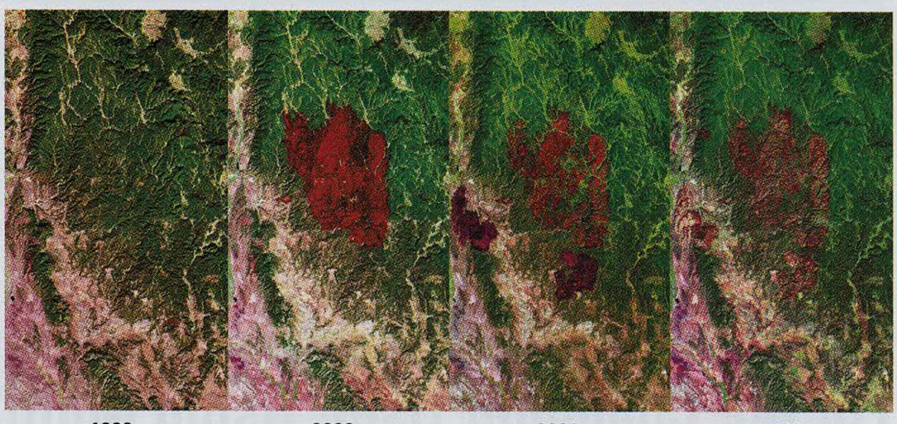
8. To change bands, click Processor, then click Display Image to display screen.
9. Experiment with different band combinations to find those that are best for seeing roads, vegetation, lakes, and so on.



For the Non-Computer User: A Classroom Activity Guide

Image Set 1
Black Hills, South Dakota

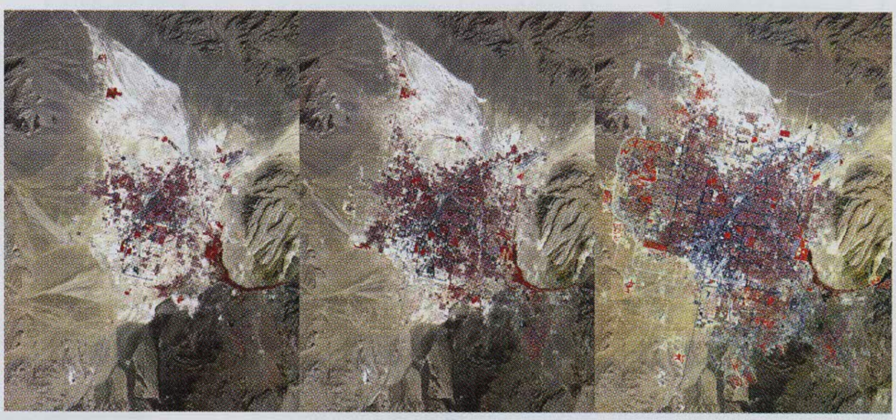
1. What color are fire scars in these images? (shades of red)
2. Fire has the ability to change the landscape over a short period of time. What changes can you see from these images? (see background material)



1999 2000 2001 2002

Image Set 2
Las Vegas, Nevada

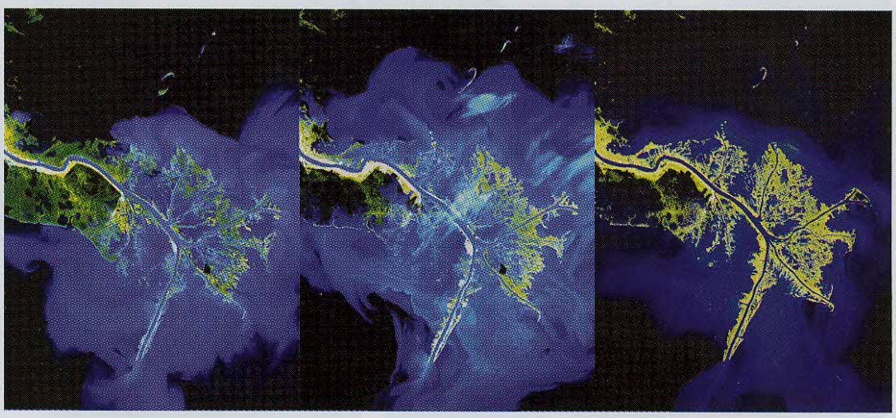
1. What do you think the red spidery looking places on the images are? (golf courses)
2. The areas in purple represent concrete or roads on the images. Find two areas that have dramatically changed over time. (runway in the upper-right; middle of image)
3. In which direction would you predict the city of Las Vegas is least likely to expand in the future? (to the east; mountains are in the way)



1972 1986 2000

Image Set 3
Mississippi Delta, Louisiana

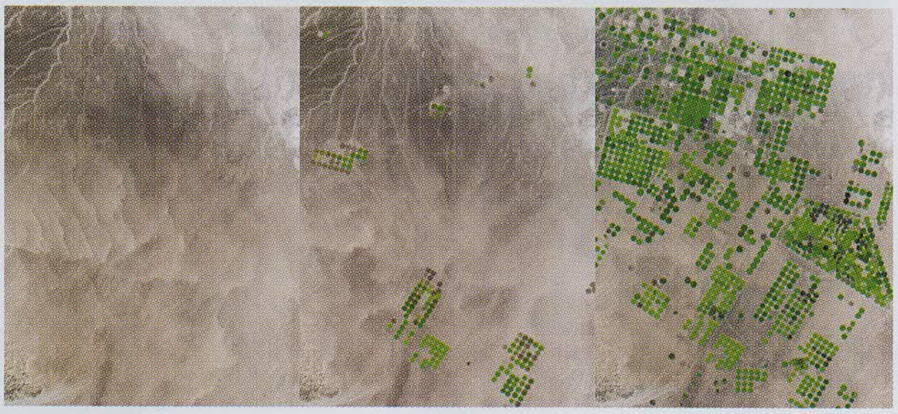
1. Describe how the delta area has changed from image to image. Find the marsh areas along the southern edge of the delta on the left side. Note the decrease. The seafood industry is concerned about this decrease. Why? (see background material)
2. New marsh is emerging within the toes of the birdsfoot area of the delta. Explain how this is happening. (see background material)



1973 1989 2003

Image Set 4
Al Isawiyah, Saudi Arabia

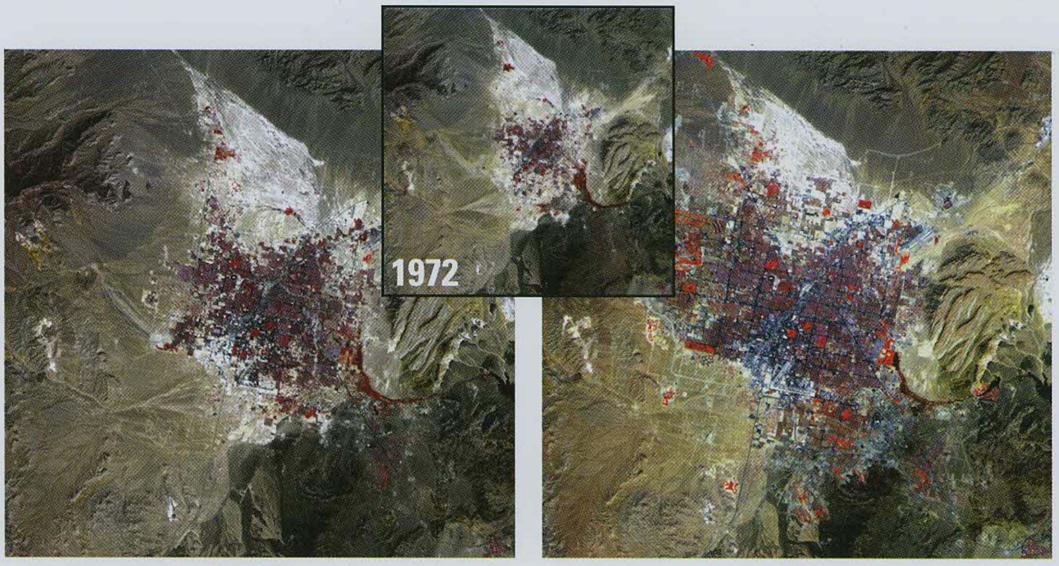
1. What do you think the green circles are? (see background material)
2. Why have they appeared? (see background material)
3. Where does the water come from to irrigate? (see background material)



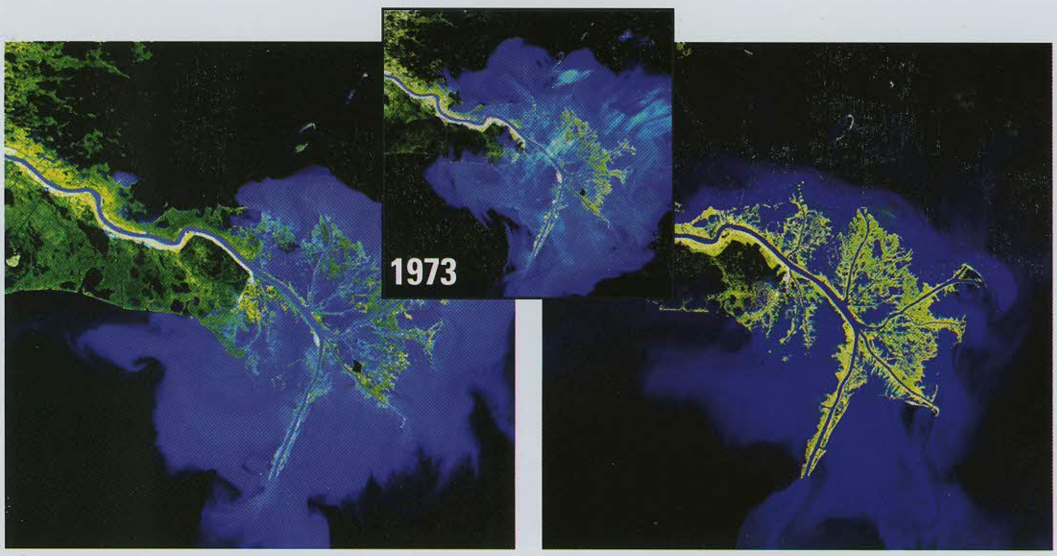
1986 1991 2000

Las Vegas, Nevada

Las Vegas is currently the fastest growing city in the United States. Back in 1950, the city's population was less than 25,000. Today it is more than one million, not including all the tourists! These three Landsat images show Las Vegas in 1972, 1986, and 2000, respectively.



1986 2000



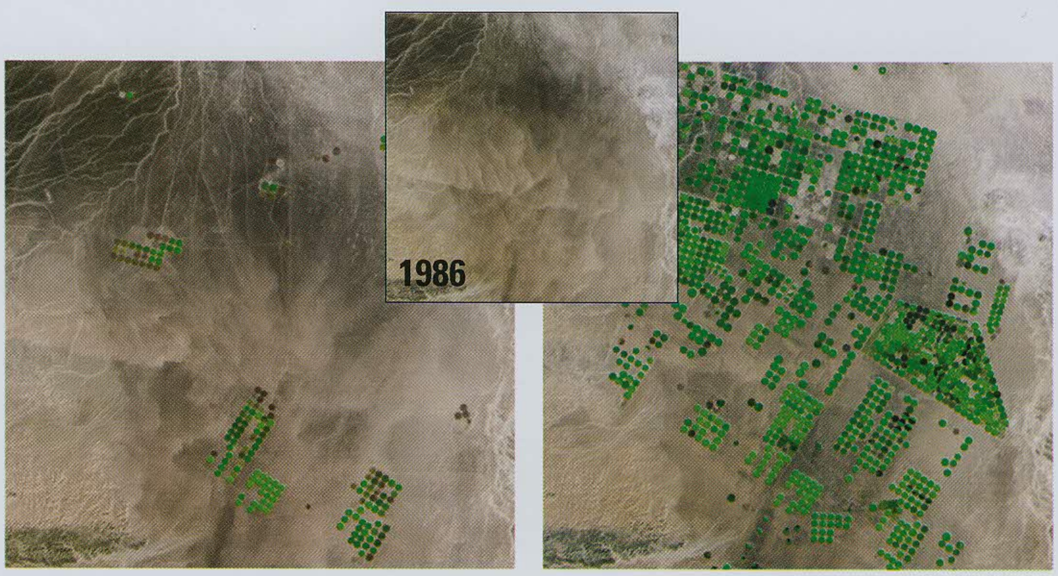
1989 2003

Mississippi Delta, Louisiana

This set of Landsat images shows three decades of change in the Mississippi River delta, where the river flows into the Gulf of Mexico near New Orleans, Louisiana. The delta changes shape and size over time. It is formed by sand and mud that have been carried downstream in the river water. When the Mississippi reaches the Gulf, it slows down and the sediments in the water settle to the bottom, creating the fan-shaped or "birds-foot" delta.

Al Isawiyah, Saudi Arabia

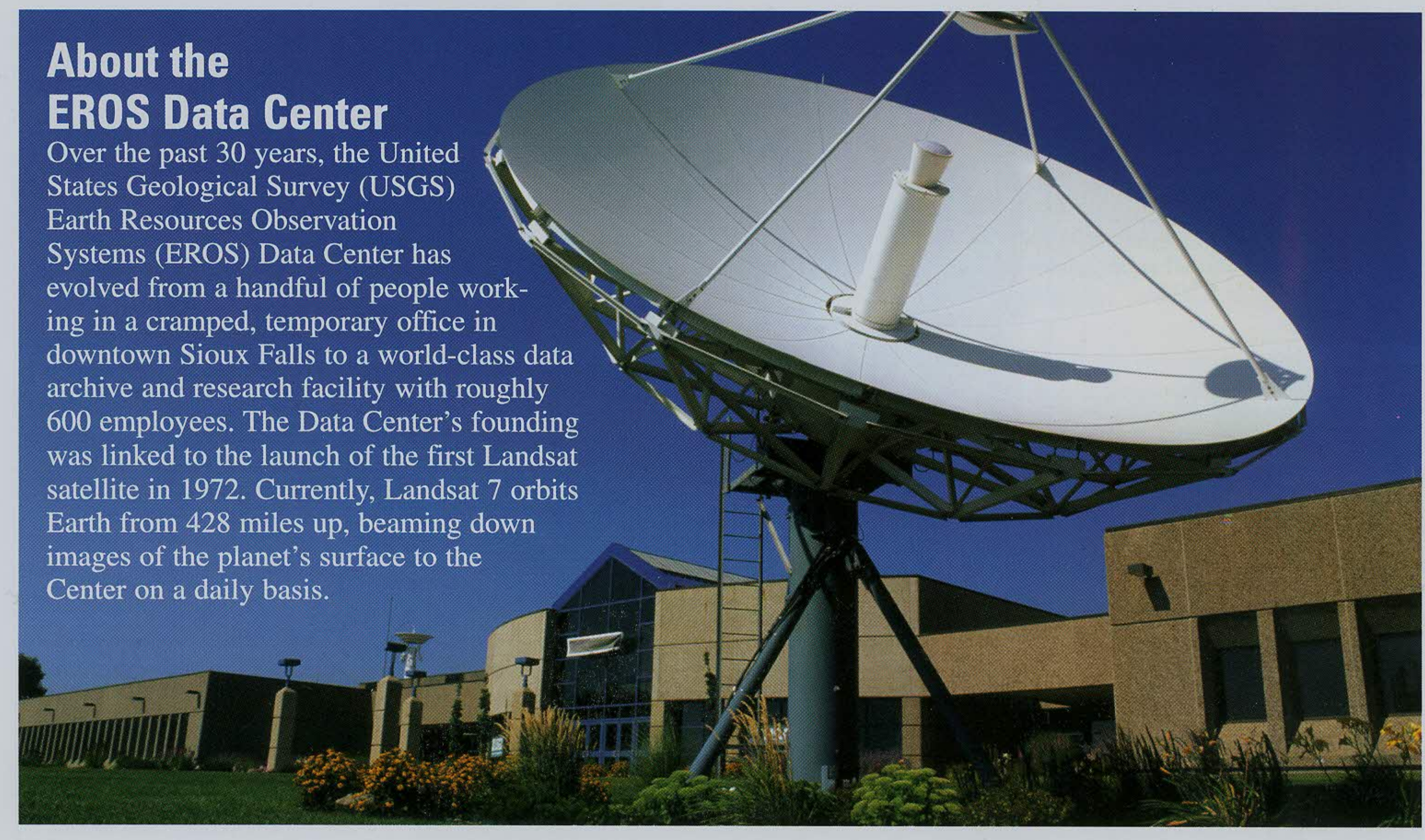
Saudi Arabia is an arid country in the Middle East. Although Saudi Arabia is rich in oil reserves, water is scarce. To meet a growing demand for wheat, the government used money from the oil industry to install center pivot irrigation systems in agricultural areas. These three satellite images show a desert-like region near the Saudi Arabian village of Al Isawiyah in the far north of the country, near its border with Jordan. They were taken before, during, and after the introduction of center pivot irrigation systems. The green circles in the images are irrigated fields.



1991 2000

About the EROS Data Center

Over the past 30 years, the United States Geological Survey (USGS) Earth Resources Observation Systems (EROS) Data Center has evolved from a handful of people working in a cramped, temporary office in downtown Sioux Falls to a world-class data archive and research facility with roughly 600 employees. The Data Center's founding was linked to the launch of the first Landsat satellite in 1972. Currently, Landsat 7 orbits Earth from 428 miles up, beaming down images of the planet's surface to the Center on a daily basis.



In August 1973, the Mundt Federal Building was completed 16 miles northeast of Sioux Falls to house the Data Center and its growing archive. That growth continues today. EROS maintains one of the largest collections of remotely sensed images of the Earth's land surface. Most come from Landsat and other civilian satellites, including weather satellites and NASA's Terra, Aqua, and EO-1 satellites. The Center also houses an extensive collection of aerial photographs. All told, the archive contains more than 28.5 million remotely sensed images. The total number grows by roughly 9.8 million every year.

The EROS staff manages and distributes archived images to scientists, policy makers, and educators worldwide who use them in the study of natural hazards, environmental change, economic development, and conservation issues. Researchers at EROS also use powerful computer systems to process and analyze satellite data in new ways. Every advance enhances our understanding of the Earth, how it changes over time, and the implications of those changes for people and ecosystems worldwide.

For more information contact:

U.S. Geological Survey
EROS Data Center
Sioux Falls, South Dakota 57198
Phone: 605-594-6511
E-mail: edcweb@usgs.gov
Internet: http://edc.usgs.gov